Municipal Solid-State
STREET LIGHTING
CONSORTIUM

Calculating Light Loss Factors for LED Street Lighting Systems

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References

- ANSI/IES RP-8-2000, American National Standard Practice for Roadway Lighting
- IESNA Lighting Handbook, 9th ed.
- LEDs in the Real World, Bruce Kinzey, PNNL, DOE SSL R&D Workshop 2010, Raleigh, NC
- Cree Data Sheets

Why LLF?

- Luminaires age, and unlike good wine they don’t get better with time
- RP-8 specifies “Minimum Maintained Average” lighting levels
- Safety
- Security
- Commercial interests
- Community pride

Factors Affecting LLF in SSL Luminaires

Maintenance Factors

- Lamp (Source) lumen depreciation – LLD
- Luminaire dirt depreciation – LDD
- System burnout or failure
- Changes in local conditions

Equipment Factors

- External ambient temperature effects – TED
- Luminaire heat extraction
- Voltage (Power, Transients)
- Ballast (PSU) & Lamp (LED) Factors
- Luminaire component depreciation

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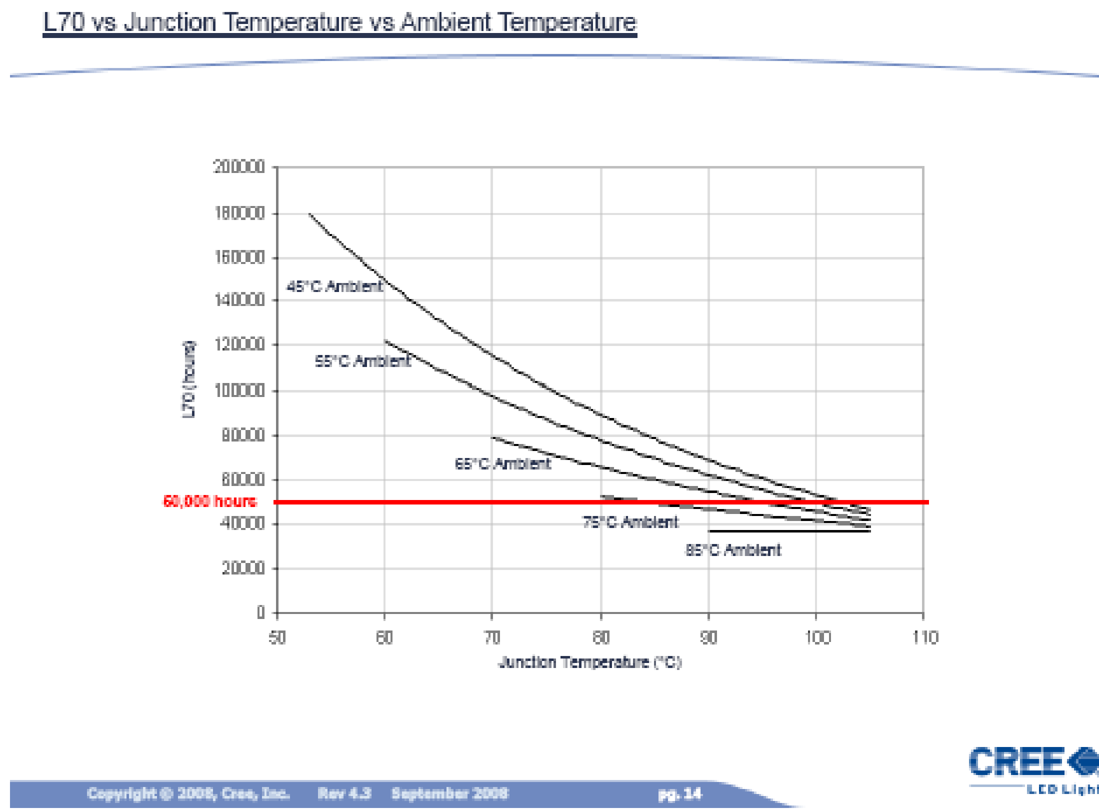
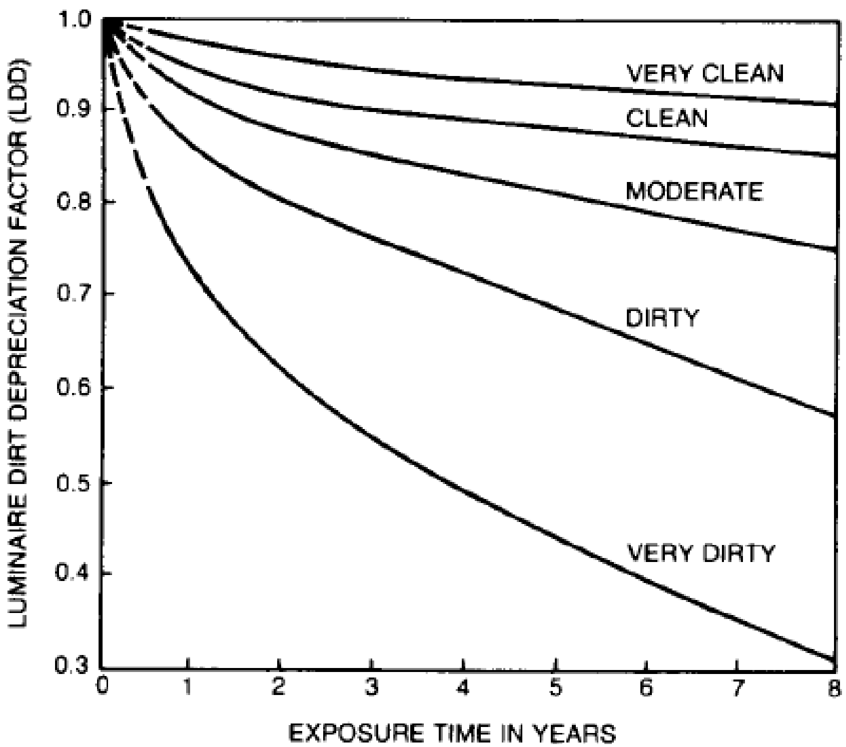
LED Lumen Depreciation - LLD

- Lumen Maintenance is a function of T_j and T_a within the LED package
- L_{70} is commonly used to define the useful life of an LED system, use LLD= 0.7, or
- Define system life and determine LLD (see future IES TM-21)



Luminaire Dirt Depreciation - LDD

ANSI / IESNA RP-8-00



SELECT THE APPROPRIATE CURVE IN ACCORDANCE WITH THE TYPE OF AMBIENT AS DESCRIBED BY THE FOLLOWING EXAMPLES:

VERY CLEAN—No nearby smoke or dust generating activities and a low ambient contaminant level. Light traffic. Generally limited to residential or rural areas. The ambient particulate level is no more than 150 micrograms per cubic meter.

CLEAN—No nearby smoke or dust generating activities. Moderate to heavy traffic. The ambient particulate level is no more than 300 micrograms per cubic meter.

MODERATE—Moderate smoke or dust generating activities nearby. The ambient particulate level is no more than 600 micrograms per cubic meter.

DIRTY—Smoke or dust plumes generated by nearby activities may occasionally envelope the luminaires.

VERY DIRTY—As above but the luminaires are commonly enveloped by smoke or dust plumes.

Figure A5. Luminaire Dirt Depreciation (LDD) factors.

Luminaire Cleaning

- Get recommended cleaning procedures from luminaire manufacturers to get them to “like new” condition.
- Evaluate location types as to degree of depreciation. i.e. residential, commercial, industrial, construction, etc.
- Perform an economic analysis by type of location to determine optimum cleaning frequency.
- Establish cleaning schedules by location based on conditions and economic analysis.
- Do periodic audits to verify the procedure is working.

LDD Field Determination

- Remove existing luminaire in retrofit area of known length of service since last cleaning. Test, clean, and re-test to establish % LDD.
- Testing can be performed by a lab or by using a homemade black box and light meter to establish relative difference.

Summary of Lab LDD Measurements

LDD ~ 3-5% per year

Site	Product	Years of Operation	Lumens Dirty	Lumens Clean	Dirt Depreciation*
I-35W	10-bar Edge	1.25	14520	15227	**4.6%**
I-35W	10-bar Edge	1.25	14670	15245	**3.8%**
Oakland	3-bar Edge	2	3738	4182	**10.6%**
Oakland	LEDWay	1.5	2866	3059	**6.3%**

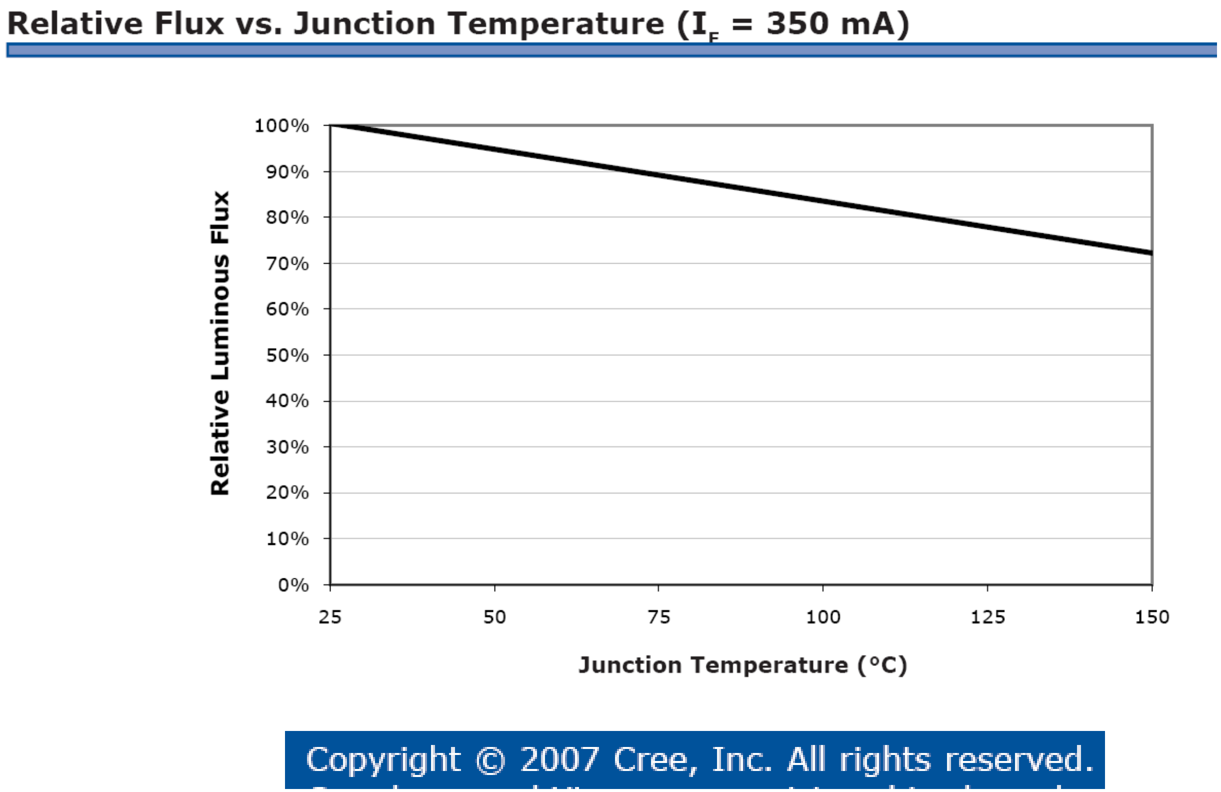
*Within ±1% lab testing error

Changes in Local Conditions

- Pavement condition and future street paving
- Construction
- Trees and vegetation
- Changes in adjacent land use
- Atmospheric conditions, smog index, etc.

External Ambient Temperature Effects

- LM-79 and LM-80 testing performed in 25°C ambient



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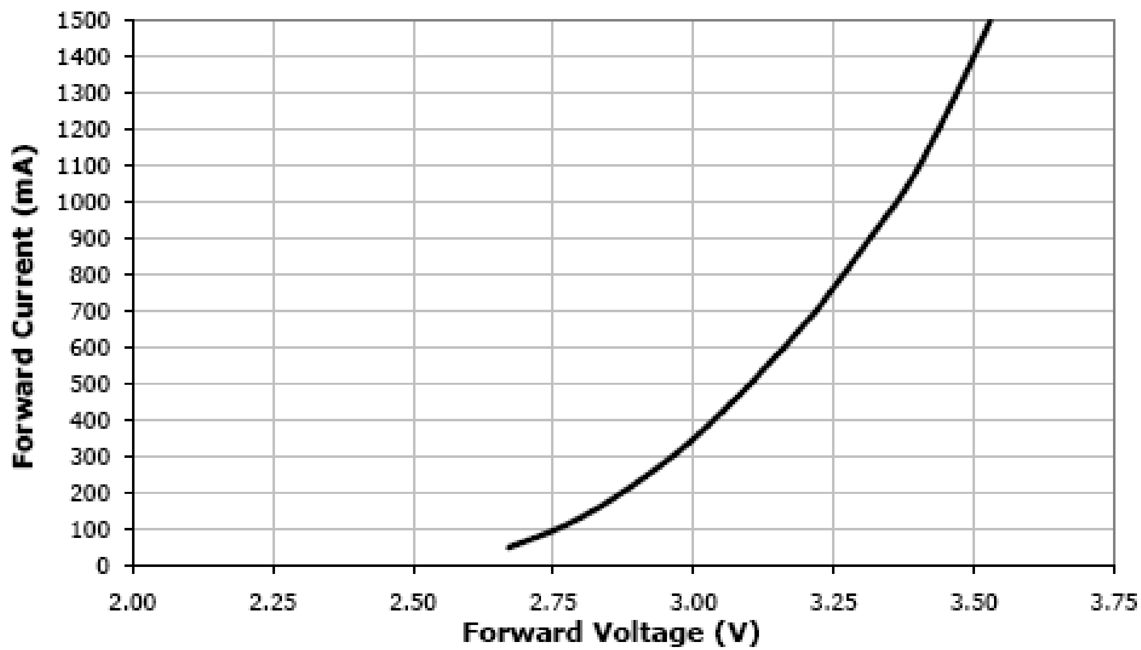
Drive Current vs. Forward Voltage

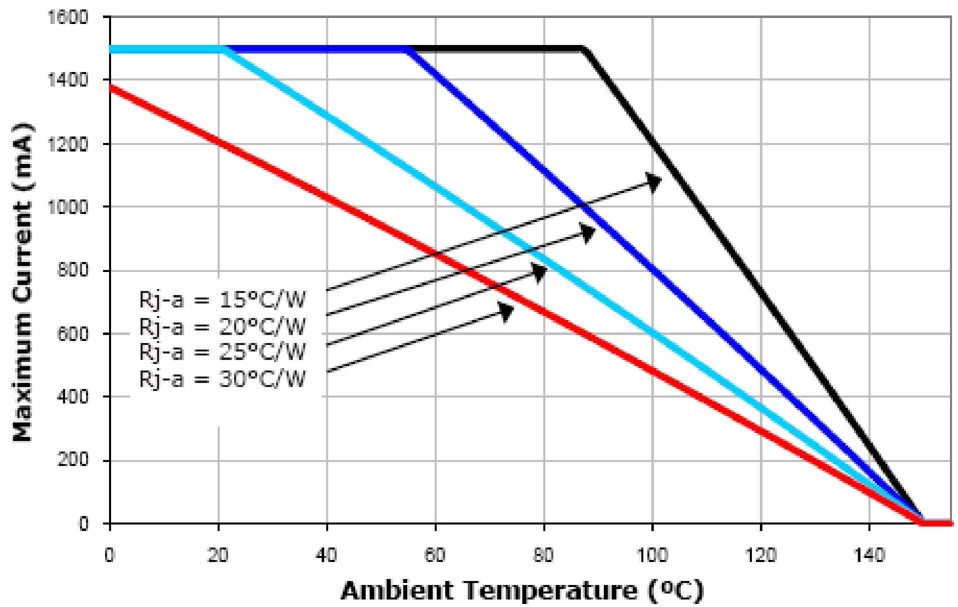
Electrical Characteristics (T_J = 25°C)



Ambient Temperature Effects

Thermal Design

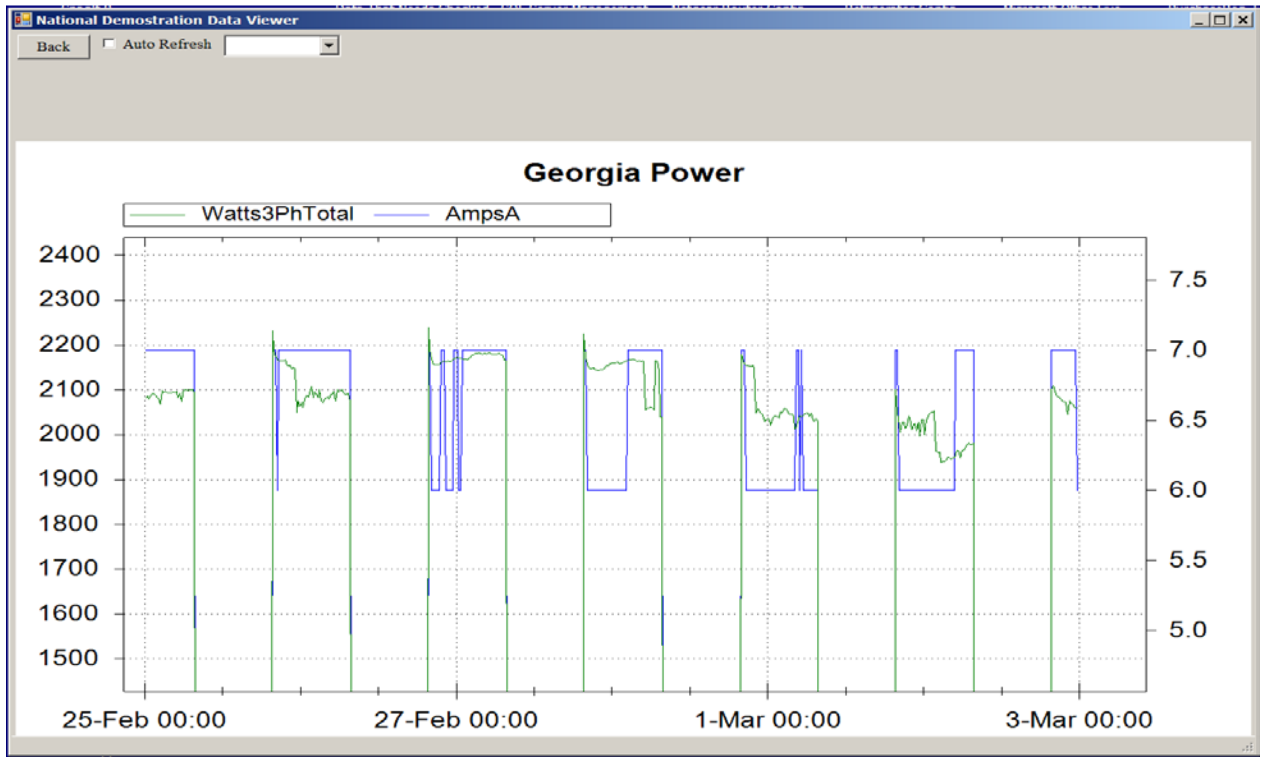
The maximum forward current is determined by the thermal resistance between the LED junction and ambient. It is crucial for the end product to be designed in a manner that minimizes the thermal resistance from the solder point to ambient in order to optimize lamp life and optical characteristics.



Luminaire Thermal Capacitance and ΔT Effects

- As T_j increases, V_f decreases and input power decreases
- Internal and external ambient changes can affect T_j and V_f

Values in this chart are not significant. This data is only given to show that a relationship exists.



Courtesy of Mike Stevens, Georgia Power

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I-35W Illumination Readings

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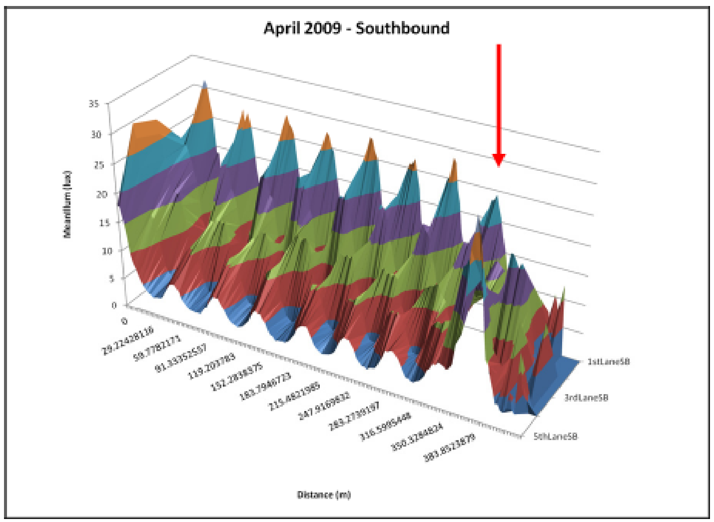

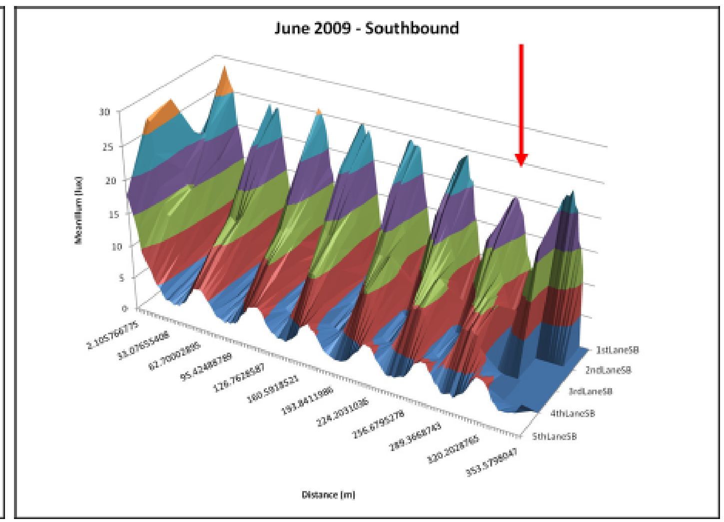

- Continuing decrease detected in avg illumination on the ground, roughly 12% from initial after a few months
- One pole location of particular concern

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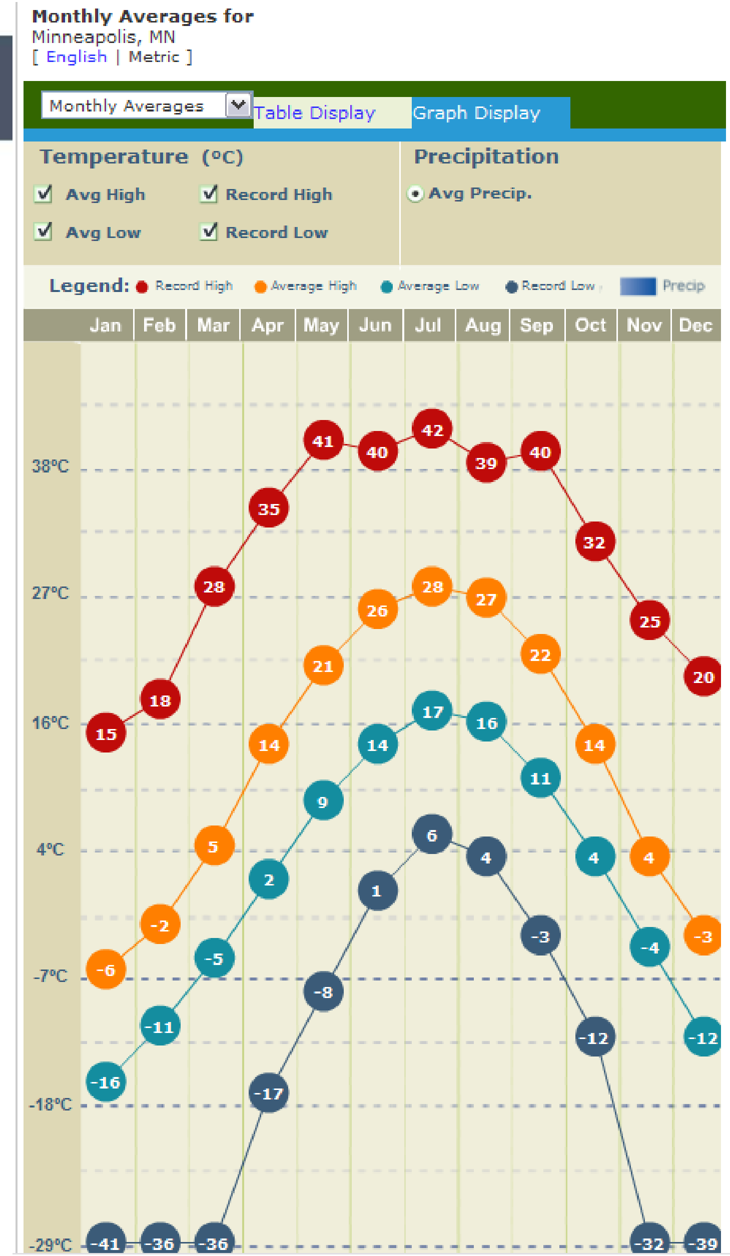
Ambient Temperature Effects

- April avg. = 14ºC
- June avg. = 26ºC
- Δ T = 12ºC
- Δ E ~ 5%



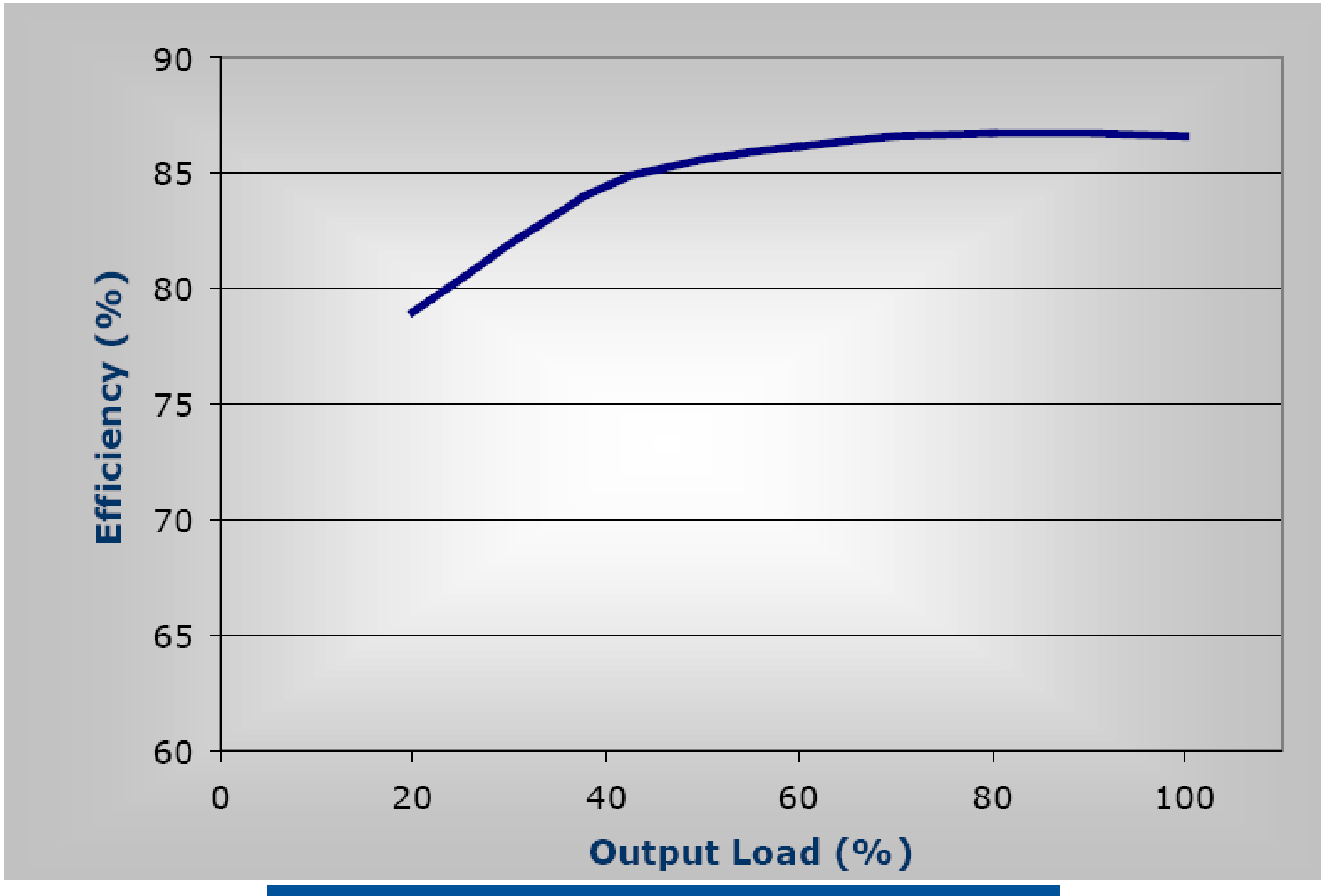
Voltage (Power, Transient) Effects

- Most PSU's operate between 120V and 277V, however efficiency varies with input voltage, get the facts!
- 480V is a more expensive option, 480V PSU's are more expensive and less reliable. Step down transformers add cost and reduce system efficiency.
- There is still much to learn about transient effects on LED systems

Ballast (PSU) and Lamp (LED) Factors

- Generally this is ≥ 0.95 for HID systems and often assumed to be 1.0
- Most drivers are constant current DC to the LED
- Some drivers supply AC to the LED to increase system efficiency (beware of flicker)
- Some drivers have fixed drive currents and some are adjustable
- Dimming circuits vary in design and operation
- Manufacturing tolerances vary
- Get the variables from the manufacturer and determine if they are significant

Example LED Driver Efficiency vs. Load



Luminaire Component Depreciation - LCD

- Environmental effects such as (acid) rain, exhaust fumes (hydrocarbons), UV exposure, humidity, vibration, salt spray from ice and snow treatments, coastal conditions, etc. affect the surfaces of optical components, conductors, fasteners, etc. (DHMO is the worst)
- Thermal cycling and aging affects plastic materials, rubber gaskets and wire insulation.
- Require manufacturers to furnish test results to quantify these and determine if it is significant for the given system.

LLF Calculation Procedure

- Use the LLF checklist provided or develop your own.
- Determine if factors are significant or not. Document, be prepared to defend your reasoning.
- All factors are ≤ 1.0. (The only exception to this is if your maximum operating external ambient temperature is significantly below 25ºC or you have consistently heavy winds.)
- Multiply them together to get LLF.

  Ex. LLF = LLD x LDD x TED x LCD …
- Use this LLF in your lighting calculations and planning.

Minimum Recommended Depreciation

- LLD = 0.70, for L_{70} lifetime rating
- LDD = 0.9, for very clean environments

- LLF = 0.70 x 0.9 = 0.63

Q&A